The neural computation of scalar implicature

Joshua K. Hartshorne
Jesse Snedeker
&
Albert Kim

This talk takes exactly 20 minutes, so if you have questions, we’ll have to discuss them offline. Sorry.
In the study I am presenting, I will be comparing sentences like these, testing the hypothesis that the phrase “the rest” is felicitous in the first sentence but not the second. Whether this is true will have some important implications on our theories of language -- pragmatics in particular. Since we’ll be recording EEGs, it will also tell us something about the neural processing of pragmatics. And it’s going to take a few minutes for me to set everything up, so please bear with me.

There is this intuitive distinction between interpreting a sentence literally and reading between the lines.
So “Can you pass the salt” is literally a question about your salt-passing abilities, but it’s also a request that the salt be passed.
“Should you really be doing that” is a question, but it’s also a suggestion. [PAUSE] And then, there is the veiled threat.
“Nice conference you have here. It would be a shame if anything happened to it.”

[PAUSE] Examples like these have generated a great deal of interest for many decades, both for what they say about the division of labor within language, and because they suggest rich social reasoning underlies everyday language interpretation. Interestingly, while researchers have discussed a wide variety of these pragmatic inferences, much of the empirical work has focused on a single phenomenon: scalar implicature. Here’s an example:
“Sally ate some of the cookies”

What is said:
Sally ate at least a few of the cookies.

What is implicated:
Sally did not eat all of the cookies.

[READ] “Some” isn’t the only word that does this. For instance, consider the sentence
“Sally ate cookies or cake”

What is said:
Sally ate at least one of the following: cookies, cake.

What is implicated:
Sally did not eat cookies and cake

[READ] Similarly, consider
“The cookies were good”

What is said:
The cookies were good

What is implicated:
The cookies were not great

[READ] In this talk, I’ll be focusing on the word some,
What is said:
Sally ate at least some of the cookies.

What is implicated:
Sally did not eat all of the cookies.

but what I say applies also to these other examples.
BTW some of you might be tempted by the possibility that maybe there isn’t any reading between the lines going on here: “some” just means “some but not all”. Perhaps the clearest reason to reject this otherwise intuitive possibility is revision. Normally, if a sentence entails something to be true, you can’t back off that entailment without contradicting yourself. Consider the following conversation
“Sally ate some of the cookies”

A: Did Sally eat some of the cookies?
B: Yes, Sally ate some of the cookies. In fact, she ate none of them.

[READ] There is something deeply wrong with what Speaker B said. But the following conversation is just fine.
“Sally ate some of the cookies”

A: Did Sally eat some of the cookies?
B: Yes, Sally ate some of the cookies. In fact, she ate none of them.

A: Did Sally eat some of the cookies?
B: Yes, Sally ate some of the cookies. In fact, she ate all of them.

[READ] [PAUSE] A number of studies using a variety of paradigms show that scalar implicatures are calculated incrementally and online, well before the end of the sentence. [PAUSE] So why do we make these “some-but-not-all”, “or-but-not-and”, “good-but-not-great” inferences? The intuition, going back at least to John Stewart Mill, is as follows
“Sally ate some of the cookies”

If Sally ate all of the cookies, the speaker would have said so because it is the more informative statement. The speaker did not say so, so it must not be the case that Sally ate all of the cookies. Sally ate some but not all of the cookies.

[READ] This account invokes some rich social reasoning. Of course, we need to cache out this notion of “more informative”. The best candidate is entailment.
Whenever “Sally ate all of the cookies” is true, “Sally ate some of the cookies” must also be true. But just because Sally ate some of the cookies does not necessarily mean she ate all of them. So “Sally ate all of the cookies” entails that Sally ate some of the cookies, and thus is more specific, gives us more information, is more informative. Since the speaker didn’t say it, then following Mill’s logic, it must not be true.
**Stated**: Sally ate some of the cookies.

**Implicated**: not(Sally ate all the cookies.)

[PAUSE] Unfortunately, this account overgenerates. “Sally ate some of the cookies” is also entailed by

Sally ate all of the cookies. $\Rightarrow$ Sally ate some of the cookies.
“Sally ate some of the cookies and likes scuba diving.” So now, by implication, it is not the case that Sally ate some of the cookies AND likes scuba diving. So she must not like scuba diving.
Stated: Sally ate some of the cookies.
Implicated: not(Sally ate all the cookies.)
not(Sally likes scuba diving.)

[PAUSE] This is obviously absurd: we don’t assume, just because someone tells us that Sally ate some of the cookies, that she doesn’t like scuba diving. It gets worse, though, since there’s another sentence that entails “Sally ate some of the cookies”
Sally ate some of the cookies and does not like scuba diving. [PAUSE] So now, by implication, Sally not only does not like scuba diving, but she also does.
**Stated**: Sally ate some of the cookies.

**Implicated**: not(Sally ate all the cookies.)
not(Sally likes scuba diving.)
not(Sally doesn’t like scuba diving.)

<table>
<thead>
<tr>
<th>Sally ate all of the cookies.</th>
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One way out of this tailspin is to post lexical scales. That is, there are certain sets of lexical items ordered in terms of informativeness — some, all; or, and; good, great — and scalar implicature only operates on alternatives in this set. So when you hear “some” could consider the stronger possibility “all” because it’s on the same scale, and you generally don’t consider possibilities off the scale. Now you can get what are called “ad hoc” implicatures with enough contextual support.
So here whether Sally likes scuba diving has been made a question under discussion. But what distinguishes words on these lexicalized scales is that they are treated as alternatives to one another even without being made the topic under conversation. There have been some attempts to provide alternatives to these lexicalized scales, but it remains by far the dominant approach. Given this role of lexicalized scales, and given that people make these inferences rapidly online, one hypothesis that quickly occurs to most psycholinguists is that perhaps this is a primarily lexical process. It would look something like this
Lexical-Level Implicatures

**Stated:** Sally ate some of the cookies.

**Implicated:**

On encountering a sentence like “Sally ate some of the cookies”, you automatically infer the same sentence but with the stronger term from the scale negated.
Lexical-Level Implicatures

**Stated:** Sally ate some of the cookies.

**Implicated:** Sally ate not([stronger term]) of the cookies.

where a stronger term from the same lexicalized scale has been inserted. In this case, that is the word
Lexical-Level Implicatures

**Stated**: Sally ate some of the cookies.

**Implicated**: Sally ate not(all) of the cookies.

“all”.

[PAUSE] And so the entire statement is interpreted as
“Sally ate some but not all of the cookies”. [PAUSE] And so it looks like the further we drill down into scalar implicature, the less it looks like an illustration of
Social reasoning about what speakers may or may not have said, what is more or less informative, instead we have what looks perhaps like some kind of rote lexical process.

[PAUSE] Interestingly, theoretical linguists for a variety of reasons have mostly stuck with Mill’s account on which scalar implicature is about informativity and thus maybe about social reasoning as well. In most studies of scalar implicature, the differences are minimal.
Lexical-Level Implicatures

**Stated:** Sally ate some of the cookies.

**Implicated:** Sally ate not(all) of the cookies.

**Conclusion:** Sally ate some but not all of the cookies.

Proposition-Level Implicatures

**Stated:** Sally ate some of the cookies.

**Implicated:** not([stronger sentence])

**Conclusion:**

So here the stronger sentence gets negated. Again, we still use the lexical scale: the alternative sentences considered are the ones that involve other items from the same scale. In this case, that’s
**Lexical-Level Implicatures**

- **Stated**: Sally ate some of the cookies.
- **Implicated**: Sally ate not(all) of the cookies.
- **Conclusion**: Sally ate some but not all of the cookies.

**Proposition-Level Implicatures**

- **Stated**: Sally ate some of the cookies.
- **Implicated**: not(Sally ate all of the cookies.)
- **Conclusion**: Sally ate all of the cookies. [PAUSE] The ultimate conclusion is the same, though, which is
Lexical-Level Implicatures

**Stated**: Sally ate some of the cookies.

**Implicated**: Sally ate not(all) of the cookies.

**Conclusion**: Sally ate some but not all of the cookies.

Proposition-Level Implicatures

**Stated**: Sally ate some of the cookies.

**Implicated**: not(Sally ate all of the cookies.)

**Conclusion**: Sally ate some but not all of the cookies.

Sally ate some but not all of the cookies. It turns out, though, this is not always the case.
The sentences we’ve been dealing with are called “upward entailing”: the sentence with “all” entails the sentence with “some”. As far as I can tell “upward” just means “normal.” But you can switch the direction of entailment in several ways. You can make the sentences conditionals.
Upward-entailing

Sally ate all of the cookies. \implies Sally ate some of the cookies.

Downward-entailing

If Sally ate all of the cookies, q. \iff If Sally ate some of the cookies, q.

[READ]. Here I say “q” here just to make it fit on the slide, but you can imagine whatever proposition you like filling in there. If Sally ate some of the cookies, then it is raining outside. The important thing, is the direction of entailment has changed. Whenever it is the case that if Sally ate some of the cookies, q, then it is also the case that if Sally ate all of the cookies, q.

[PAUSE] Relative clauses do the same thing.
Whenever it is the case that everyone who ate some of the cookies, \( q \), then it is also the case that everyone who ate all of the cookies, \( q \).

And there are other so-called “downward-entailing” contexts, too.

[PAUSE] This distinction between upward- and downward-entailing sentences is completely irrelevant to the lexical-level account, and you get the some-but-not-all interpretation regardless.
Lexical-Level Implicatures

**Stated:** If Sally ate some of the cookies, \( q \).

**Implicated:** If Sally ate not(all) of the cookies, \( q \).

**Conclusion:** If Sally ate some but not all of the cookies, \( q \).

Here’s what it would look like. [PAUSE] The proposition–level account does care, because the proposition level account cares about the relative informativity on the sentence as a whole.
“If Sally ate some of the cookies, q” is already the strongest sentence on its scale; the speaker couldn’t have said anything more informative -- at least not involving another word on the scale -- so there is nothing to negate.
### Lexical-Level Implicatures

**Stated:** If Sally ate some of the cookies, \( q \).

**Implicated:** If Sally ate not(all) of the cookies, \( q \).

**Conclusion:** If Sally ate some but not all of the cookies, \( q \).

### Proposition-Level Implicatures

**Stated:** If Sally ate some of the cookies, \( q \).

**Implicated:** [nothing]

**Conclusion:**
Lexical-Level Implicatures

Stated: If Sally ate some of the cookies, q.
Implicated: If Sally ate not(all) of the cookies, q.
Conclusion: If Sally ate some but not all of the cookies, q.

Proposition-Level Implicatures

Stated: If Sally ate some of the cookies, q.
Implicated: [nothing]
Conclusion: If Sally ate some of the cookies, q.

So the final interpretation is “If Sally ate some of the cookies, q”. That is, you don’t get the “some but not all” interpretation.

[PAUSE] The debate in linguistics has been largely between folks who argue that scalar implicature is *always* calculated at the proposition level and those who argue that it’s just *usually* calculated at the proposition level. BTW In linguistics, instead of saying “lexical implicature” they usually say “local implicature”; the meaning is slightly different but the differences won’t be relevant in this talk; I’m happy to address them later.

So far, there is only limited empirical data. Ira Noveck and colleagues presented participants with logical reasoning problems like this
Lexical- vs. Proposition-level Implicatures

If there is a P or a Q then there is an R.
There is a P.
There is a Q.
Is there an R?

(Noveck et al., 2002)

[READ]. The results were consistent with largely proposition-level reasoning, with participants answering that yes, there is an R. [PAUSE] Two other studies addressed the issue using a different methodology. Guerts & Pouscoulous (2009) presented participants with questions like this...
Lexical- vs. Proposition-level Implicatures

If there is a P or a Q then there is an R.
There is a P.
There is a Q.
Is there an R?

(Noveck et al., 2002)

 ambush by answering 'The sentence could be either true or false'.

Even though participants were able to recognize other kinds of
ambiguities, none of them reported that the target sentence (6) could
be either true or false in a situation such as the one depicted in Figure 1.

Geurts and Pouscoulous interpreted these results as showing that the local
reading is not a possible construal of the sentence, from which they
concluded that even 'minimal conventionalism' is wrong.

2.2 Potential methodological problems

The outcome of the experiment of Geurts and Pouscoulous (2009) is
that they did not detect a particular reading. We agree that this result
casts doubt on the view that the local reading is the default reading, for
if this were so, one would expect that at least some subjects would
detect it in such a truth-value judgment task. However, the failure to
detect a particular reading in a particular experimental setting (or
various experimental settings) does not prove that the reading in
question is not one of the possible readings of the relevant sentence. As
we will see, there are a number of reasons that may explain why their
methodology failed to detect the local reading, even if it existed. We
thus object to the stronger claim that Geurts and Pouscoulous (2009)
make, i.e. the claim that embedded scalar implicatures do not exist.

In this section, we present what we view as possible limitations of Geurts
and Pouscoulous' methodology. The experiments that we will present in
the subsequent sections were designed to overcome these limitations.

(Chemla & Spector, 2010)

[READ] Participants largely answered “true”, which is consistent with the
proposition-level account. Chemla and Spector re-did this study using
what they argue is a better design, presenting participants with trials
like this...
Now participants frequently thought this was false, consistent with at least occasional lexical–level implicatures.

[PAUSE] If you are having trouble working through these examples ... well, first, the slides are on my website, so you can think through this offline, but second, that’s actually what I want you to get out of this. These are complex tasks, which can make it hard to figure out what exactly is driving the effect. In fact, there is some evidence that what we’re measuring here is not language interpretation per se, since these tasks use roughly the same language but get different answers. So we wanted to use a task that was much closer to normal everyday communication, which obviously is to have people read sentences one word at a time while electrodes are strapped to their head.

[PAUSE] Actually, seriously, one of the nice things about EEG is that the measures are implicit: you don’t have to worry as much about task demands, because there is no task, and so hopefully this gives us a relatively direct window on processing. Here are our stimuli:
Sally ate some of the cookies this morning before breakfast and the rest are on the counter.

If Sally ate some of the cookies this morning before breakfast then the rest are on the counter.

[READ] Our primary interest is what happens at “the rest”.
Sally ate some of the cookies this morning before breakfast and the rest are on the counter.

If Sally ate some of the cookies this morning before breakfast then the rest are on the counter.

If you interpret “some” as meaning “some but not all”, then we’ve got two sets of cookies.
cookies eaten by Sally and cookies not eaten by Sally. Now, when you come across a reference to “the rest”, it’s immediately obvious what this anaphoric phrase is referring to:
Sally ate some of the cookies this morning before breakfast and the rest are on the counter.

If Sally ate some of the cookies this morning before breakfast then the rest are on the counter.

the remaining cookies. However, if you haven’t made an implicature, you can’t divide the set of cookies up. For all you know, Sally ate all the cookies and there are no remaining cookies.
Declarative
Sally ate some of the cookies this morning before breakfast and the rest are on the counter.

Conditional
If Sally ate some of the cookies this morning before breakfast then the rest are on the counter.

[unclear]

in which case, it’s not clear what “the rest” refers to.

[PAUSE] Now, on the proposition-level implicature account, the “some-but-not-all” reading occurs in declarative sentences and not conditional sentences. So we should get a difference in how easy it is to interpret “the rest”
[PAUSE] Now you *might* worry that declaratives and conditionals are different in ways unrelated to scalar implicature, and that these differences could drive any effects we see. Well, we worried to. So we included a control condition by everywhere changing “some” to “only some”
“only some” always means some but not all, and so any remaining differences between the conditions is strictly due to differences between declaratives and conditionals and not due to differences in the interpretation of “some”. I’ll call this
“control sentences” and I will call the original sentences the
“critical sentences”. And so what we are interested in is the 2x2 interaction.

[PAUSE] Now, there are a couple previous EEG studies of scalar implicature that are relevant, but I think everyone’s impatient to see the results, so I’m going to defer discussing them for the moment. I do want to remind you what is at stake. If the proposition–level account is correct, the at least potentially
scalar implicature really is about reasoning about informativity and thus possibly speaker intent. Alternatively, if the lexical–level account is correct
scalar implicature is probably more about lexical and grammatical processes and at best peripherally related to informativity. Either way, we’d know something new about language, but keep in mind that scalar implicature is probably the most fully-described pragmatic phenomenon and often used as a case study for the role of social inferences in language. So there’s a lot of people’s research programs hanging on this question. [PAUSE] Now for the results
Here I’m plotting difference waves in the ERP triggered by “the rest”: the declarative sentences minus the conditional sentences. The critical sentences are in purple and on the left, and the “only some” control sentences are in red and on the right. You can see what looks like a nice interaction. If I showed you the spaghetti plots for all four conditions, you could see that this interaction is due to a positive deflection for the critical conditional sentences — that is, the sentences where “the rest” is infelicitous — relative to the other three conditions. [LONG PAUSE]

This interaction is significant from about 500ms to 1100ms. You might wonder — given that we didn’t have a priori hypotheses about where the effect might appear in the ERP — how we dealt with multiple comparison problems. We did two things: First, we used this very exciting new permutation bootstrapping analysis that eliminates issues of multiple comparison problems. I’m very happy to tell you all about it later if you ask me. Second, we replicated the study and got the same results.

[PAUSE] These results suggest that proposition–level implicature is occurring at least some of the time. I’ll return to the implications of that conclusion, but first I’m going to interpret the EEG findings themselves. We found that when the phrase “the rest” was infelicitous because of the lack of a scalar implicature, we got a sustained, frontal positivity. Naively, we might suppose that represents scalar implicature–related activity. If so, we would expect two previous EEG studies of scalar implicature to have found the same results. They did not.
Nieuwland & Kuperberg, 2010: *Some people have pets / lungs*

Nieuwland & Kuperberg had participants read sentences that are felicitous under a some-but-not-all reading (some people have pets) and sentences that were infelicitous under a some-but-not-all reading (some people have lungs), finding
a larger N400 for the infelicitous word.
Politzer–Ahles and colleagues presented participants with pictures like the one on the left or the one on the right along with the sentence
Some of the girls are sitting on blankets. Under the some-but-not-all interpretation, this is felicitous for the
picture on the left and infelicitous for the picture on the right.
This infelicity resulted in a negativity that was somewhat later than the typical N400. Why do we get positivities and they get negativities. One possibility is that negativities are related to scalar implicature cancellation -- the infelicities in these studies can be resolved by cancelling the implicature -- whereas positivities are related to scalar implicature generation -- the infelicities in our study can be resolved by retroactively computing the some--but--not--all interpretation.

[PAUSE] Alternatively, recent work by Federmeier and others shows that whereas very infelicitous stimuli result in N400s, stimuli that are plausible but somewhat unlikely result in sustained positivities, not very unlike the one we found. Indeed, in two follow-up judgment studies, we found that Nieuwland & Kuperberg's infelicitous sentences were judged to be much more implausible than ours. [PAUSE] What this would mean is that the ERPs in all three studies are more about very general revision processes rather than implicature processes *per se*. I think this is actually very interesting because it points out a direction for studying how syntactic, semantic, and pragmatic information is combined online. I mean, I think the semantic P600 debate -- which will be familiar to those of you who follow the ERP literature -- shows that we are still in the early days of really understanding what exactly it is we are measuring with EEG (and probably with MEG and fMRI as well). [PAUSE]
Lexical-Level Implicatures
- **Stated**: Sally ate some of the cookies.
- **Implicated**: not(Sally ate all the cookies.)
- **Conclusion**: Sally ate some but not all of the cookies.

Proposition-Level Implicatures
- **Stated**: Sally ate some of the cookies.
- **Implicated**: not(Sally ate all of the cookies.)
- **Conclusion**: Sally ate some but not all of the cookies.

As I already mentioned, these results argue against a strong lexical-level account, suggesting that instead implicatures are calculated at the proposition-level at least enough of the time to give us the differences between conditions. This means that scalar implicatures really are based on how informative the utterance is -- something that is not the case on the lexical-level account. That fits in nicely with some recent findings by Bonnefon & Feeney and by Bergen & Grodner and work by Noah and Andreas, which suggest that when calculating implicatures, listeners are sensitive to the speakers’ knowledge and intentions. That is, scalar implicature really is a good model of complex social reasoning during language processing. Whew!
The End

I’ll leave you with that thought. Except...
The End?

some of you might have noticed that our design was ideal for capturing scalar implicature processing itself online by looking at what happened at the word “some”. If you want to know what we found, you’ll have to ask. Or read the paper.
# Thank You

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<td>Jesse Snedeker</td>
<td>NDSEG</td>
</tr>
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<td>Al Kim</td>
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